No Safe Harbor

Most harbors in the world suffer from the constant accumulation of sediment washed into shipping channels from inland sources or rearranged on the harbor floor. This constant threat of sediment accumulation challenges commercial viability, especially as ever-larger oceangoing vessels require deeper channels to reach dock. As a matter of course, dredging is used to maintain existing channels and create new ones. The cost of dredging to remove the sediment is high, but the example of now-landlocked Bruges, Belgium—once a prosperous 14th-century port city whose city fathers chose not to dredge—is a sobering reminder of the consequences of ignoring sediment accumulation.

Sediment containing potentially hazardous amounts of chemical, organic, and metal contamination was not regarded as an environmental health concern until the 1970s, when a new awareness prompted measures that have since severely limited the ability to dispose of the material in the traditional and least expensive manner—by dumping it in the ocean. Because so much of world trade must pass through harbors, and because cost-effective alternatives to ocean dumping are limited, the world's largest trading ports such as New York/New Jersey and Rotterdam, Netherlands, have been forced to address the contaminated sediment problem in new ways and on a scale never before required.

In March 1997, the National Research Council (NRC), in its document *Contaminated Sediments in Ports and Waterways: Cleanup Strategies and Technologies*, estimated that in the United States, approximately 14–28 million cubic yards of contaminated sediments—approximately 5–10% of all sediments dredged—must be managed in some way each year. According to the report, the primary reasons for managing this sediment are to identify and clean up threats to public health and wildlife, and to meet water and environmental quality standards. It also is vital, says the report, to ameliorate dredging controversies, particularly concerning the designation of disposal sites for contaminated dredged material.

Harbor sediment contamination is generally in the form of chemicals that sorb to fine-grained particles, although organic materials and metals are also a problem. These chemicals include trace metals and hydrophobic organics such as dioxins, polychlorinated biphenyls (PCBs), and polyaromatic hydrocarbons (PAHs). Concentration is often diffuse but can be concentrated in hot spots as a result of point source discharges and spills. If it is diffuse, then low-to-moderate amounts of contamination tend to extend no more than a meter into the harbor floor over a wide area.

The contamination in each harbor comes from a unique blend of sources. Common sources are industrial discharges upstream from the port. Urban populations contribute contamination through sewage discharge and automobile emissions. Suburban and agricultural sources include heavy metals, oil, pesticides, nitrogen, and phosphorus. Atmospheric pollution from distant sources is common. Ships in the port can be a major source of contamination by leaking fuel and oil into the harbor waters, and materials associated with ship repair and maintenance, such as paints and varnishes, also contribute to the problem.

This mix of contaminants in the sediment creates problems of unusual complexity for both analysis and management. Because most of the contaminants are firmly bound to fine-grained particles and are only slowly released, most risk to human health and the ecosystem is linked to long-term rather than transitory exposure. Although the extent of such risks is unknown, the most significant human health risk associated with sediment contamination may be consumption of contaminated fish and benthic creatures, such as shellfish, that dwell on the marine floor. Compounds such as PAHs are easily metabolized by the enzymatic systems of fish. Bivalve mollusks have a limited ability to metabolize PAHs and tend to accumulate and retain them in higher concentrations than fish. Trace metals do not degrade in marine environments and may be bioaccumulated by aquatic organisms and transferred to humans when they consume fish. Fish and bottom-dwelling creatures can suffer disease, death, reproductive failure, or impaired growth upon exposure to such pollutants.

Legal Framework

Historically, ensuring navigable waters has been the guiding motive for dredging and sediment management. For example, the Rivers and Harbors Act of 1899, which has been amended many times since its inception, created the basic framework for managing navigation waterways in the United States. Many state and national statutes and regulations affect sediment management and disposal, with separate and sometimes conflicting reporting and permitting requirements. Federal laws include the Resource Conservation and Recovery Act, the Clean Water Act (CWA), the Marine Protection, Research and Sanctuaries Act, the Comprehensive Environmental Response, Cleanup, and Liability Act (also known as Superfund), and the biennial Water Resource Development Acts (WRDAs), which include beneficial uses of dredged materials. Sediment permitting and removal is generally conducted by the U.S. Army Corps of Engineers (USACE) working with the EPA. The USACE is responsible for maintaining and dredging federal navigation channels. Private parties must apply to dredge to allow barges and ships access off of channels.

The International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (commonly known as the London Convention of 1972) established the most demanding approach to controlling marine contamination. "The London Convention [contributing parties] continue to meet regularly to negotiate and set standards," says Robert Engler, a senior scientist at the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi, who directs research on dredging and is a U.S. representative to follow-up meetings on the London Convention. Engler also chairs the environmental commission of the Brussels, Belgium-based Permanent International Association of Navigation Congresses (PIANC), which was established in 1885 to promote the maintenance and development of inland and ocean navigation.

The London Convention grew out of international concern that large portions of near-coastal marine waters were becoming severely degraded, and that this degradation was at least in part caused by unregulated dumping of waste materials. A global treaty came into force in 1975 and was signed by 72 nations. Engler says that the PIANC developed the most recent set of London Convention guidelines for disposing of dredged material based on bioaccumulation and biotoxicity tests. These guidelines, which were adopted in 1996, were incorporated into U.S. regulations that did not already meet the standards, and have eliminated contaminated sediment from ocean disposal.

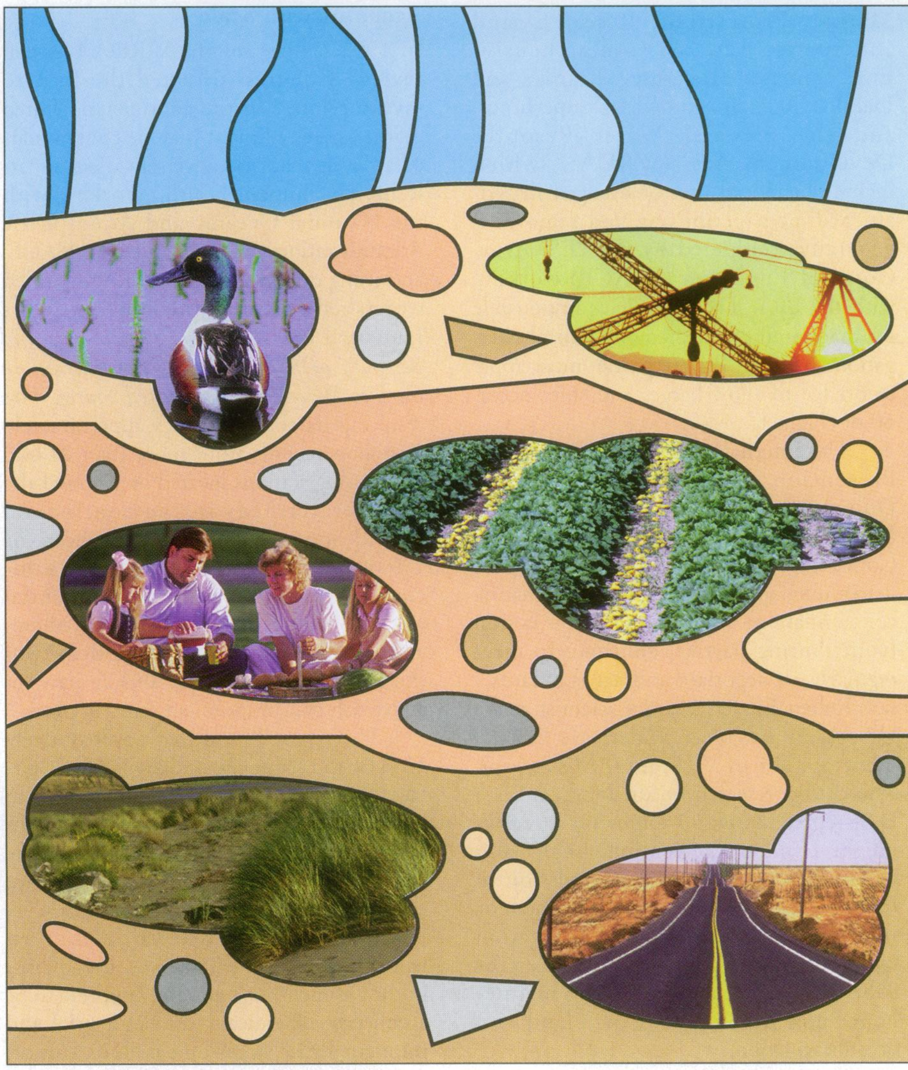
Still, most sediment disposal is not a problem. "Remember that sediment is just soil in water and that a significant percentage of dredged material is reused for beneficial purposes such as beach preservation or as sand on winter streets," Engler says. "It's a question of whether the beneficial use can be found nearby." For the contaminated sediment, however, management is a more complicated issue.

Accumulation Scale

In 1992, as part of the WRDA biennial review, Congress directed the EPA to inventory areas in the continental United States where sediment may be contaminated at levels that may adversely affect aquatic life and human health. Working with the National Oceanic and Atmospheric Administration (NOAA) and the USACE, and using existing data, the EPA identified watersheds of probable concern in its January 1998 report *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*. The resulting database includes approximately 2 million records from more than 21,000 monitoring stations located in 1,363 of the 2,111 watersheds in the continental United States. Ninety-six watersheds, or 7% of the total, were found to be sufficiently contaminated to pose potential risks to people who eat fish from them, and to fish and wildlife. More than two-thirds of these watersheds already have an active fish consumption advisory in place.

The report found that approximately 10% of the sediment underlying U.S. surface waters is sufficiently contaminated to pose potential risks to fish and to humans and wildlife eating those fish. Much of the contaminated sediment was found to have been polluted by chemicals, such as DDT, PCBs, and mercury, that have since been banned or restricted. However, they persist in the sediment for years and continue to be a concern. Chemicals from industrial and municipal discharges and polluted runoff from urban and agricultural areas continue to accumulate to harmful levels. The picture is limited because of the relative availability of electronic data from different sites, and because the characteristics and the degree of certainty of the analysis do not allow adverse effects at any one location to be determined with absolute accuracy.

"Knowing the concentrations and mixtures of toxic chemicals in sediment provides no direct measure of the toxicological significance of the chemicals," says Edward Long, a senior scientist with the NOAA in Seattle, Washington. From 1991 to 1995, the NOAA conducted a sediment toxicity survey of 22 estuarine areas in the United States. In the December 1996 issue of *Environmental Science & Technology*, Long and colleagues published results from three standardized toxicity tests for contaminated sediments—10-day amphipod survival tests with solid-phase sediments, 5-minute microbial bioluminescence tests with organic solvent extracts of sediments to determine reproductive success, and tests of porewater extracted from sedimentary



Beneficial Uses of Dredged Material

- Habitat restoration/enhancement (wetland, upland, island, and aquatic sites including use by waterfowl and other birds)
- Beach nourishment
- Aquaculture
- Parks and recreation (commercial and noncommercial)
- Agriculture, forestry, and horticulture
- Strip mine reclamation and landfill cover for solid waste management
- Shoreline stabilization and erosion control (fills, artificial reefs, submerged berms, etc.)
- Construction and industrial use (including port development, airports, urban, and residential)
- Material transfer (fill, dikes, levees, parking lots, and roads)

Source: U.S. EPA and Department of the Army U.S. Army Corps of Engineers. Evaluating environmental effects of dredged material management alternatives: a technical framework. EPA 842-B-92-008. Washington, DC: Environmental Protection Agency, 1992.

http://www.epa.gov/OWOW/oceans/framework/

rock using sea urchin or mollusk embryos. Different tests often identified different samples as toxic, but in all areas measures of toxicity showed associations with complex mixtures of aromatic hydrocarbons, trace metals, and chlorinated organic substances, and these associations were strongest where toxicity was most severe.

The relatively good news was that the amphipod survival tests, which are the most ecologically relevant, clearly indicated that toxicity is not widespread throughout all the estuaries surveyed. Instead, it appears that toxic conditions are usually restricted to small regions, particularly inner maritime harbors, industrial bayous, and waterways with the highest chemical concentrations. This toxicity was most widespread in Newark Bay (85% of the area), San Diego Bay (69%), the Long Island Sound bays (50%), and the Hudson-Raritan estuary (38%).

Technologies and Controls

Clearing harbors of contaminated sediment is very site-specific work. Jack Word, director of the Battelle Marine Sciences Laboratory in Sequim, Washington, says, "You must determine what contaminants are present, the potential toxicology, and whether unconfined disposal is possible." Evaluations are needed for three types of dredging: maintenance every 1–3 years, cleanup dredging to remove contaminated material for human health or environmental purposes, or deepening projects intended to expand the capability of a harbor to accommodate the deeper and wider draft ships that may no longer pass through the Panama Canal, but rather must sail around South America.

Word says that the procedures for analyzing contaminants are a direct result of the London Convention. "We won't dump any chemicals that are persistent or greater than trace quantities," he says, adding that there are many compounding factors when evaluating sediment. For example, salinity can cause toxicity but is not persistent. Ammonia is produced naturally by biological processes in marine environments and degrades into nitrites and nitrides in upper sediments. When channels are dug to a new depth, most of the exposed sediment is not contaminated by human activity, but it may still have problems with toxicities that are not human-related. Dredging operations also must pay attention to the potential for creating toxicity by suspending particulate materials when the sediment is removed or dumped.

"Since the early 1970s, when environmental regulations took effect in Seattle, core samples showed a definite decrease in some of the chemicals being controlled, such as lead from gasoline," Word notes. "We've also seen a decrease in arsenic, copper, and silver. Off Palos Verdes [California], there's been a great decline in DDT from the sewage system." He confirms that it is much easier to track industrial pollution patterns, but that nonpoint sources such as agriculture are a large component of the total contamination in sediments and are difficult to locate.

Once harbor sediment has been characterized, it faces two paths: if it is clean or only slightly contaminated, it can be disposed of in unconfined areas or put to beneficial use; otherwise, it must be disposed of in a controlled fashion, perhaps including treatment. Depending on the composition and grain size distribution of the dredged material, clean sediment might be used beneficially for construction or as agricultural soil. Coarse materials are generally suitable for creating or improving land. Eroded beaches can be rebuilt or protected by offshore berms. And contaminated material can be capped with a layer of clean sediment to isolate it from the environment. Most clean sediment is still dumped close to shore in state-permitted areas.

Disposal can include either water or land options and can be either dispersive or confined. The effects of open water disposal are predominately physical in nature, including turbidity and smothering of living organisms. Many ocean disposal sites off the U.S. coast have been closed in recent years, including the well-known Mud Dump Site just outside the entrance to the Port of New York/New Jersey. In confined aquatic disposal, contaminated sediment is buried in a natural or man-made depression and then covered with clean sediment.

Land disposal can be desirable, but attempts to place slightly contaminated sediments in landfills have sparked considerable public opposition and are a major factor in forcing an evaluation of treatment technologies as an alternative to simple burial in pits. One land disposal option that has attracted attention is a pilot project getting underway in Pennsylvania to reclaim abandoned coal mines using contaminated sediment taken from the Delaware and Hudson rivers, and from the New York harbor. The sediment is mixed with incinerator ash and lime to create a grout-like cement that is spread on the mined land to act as a buffer against acidic drainage that has been degrading the state's streams and rivers.

As for potential treatment technologies, they are an expensive addition to the baseline costs of dredging and relocating sediment. Often, depending on such factors as type of contaminant, initial concentrations of dredged material, whether a beneficial reuse for post-treatment material exists, and the level of treatment required, the more effective the technology, the more expensive it is. The average cost of current treatment technologies averages over \$100 per cubic yard, compared to \$20 for removing and transporting sediments and \$5 for conventional navigational dredging, which does not require special disposal procedures. Costs may also vary depending on whether disposal will be in the ocean or upland. For example, according to Eric Stern, regional contaminated sediment program manager for the EPA's Region 2 in New York, unrestricted disposal at the former Mud Dump Site averaged \$6–8 per cubic yard. Capping a large dredging project (300,000–500,000 yards) with clean material in the ocean has run as high as \$40 per cubic yard. Now that the Mud Dump Site has been redesignated an Historical Areas Remediation Site, upland disposal costs average around \$45 per cubic yard. Furthermore, says Stern, these costs put smaller operators at peril since they often cannot afford to pay them. In addition, the technologies are difficult to implement, equipment-intensive, complex, and potentially hazardous—and may offer only part of the solution. Currently, work is being conducted by the EPA, the USACE, and Brookhaven National Laboratory in New York under the WRDAs of 1992 and 1996 to demonstrate the feasibility of decontaminating dredged material from New York/New Jersey harbor in an environmentally sound and cost-effective manner. The 1996 mandate requires the federal agencies to demonstrate decontamination of up to 500,000 cubic yards of port sediments. The project team has developed public–private partnerships to encourage private industry to develop and commercialize a long-term, sustainable, profit-making enterprise in decontaminating sediments with a beneficial reuse. Says Stern, "Decontamination is not the answer for everything, but [is] an integral component of an overall dredged material disposal management plan. The technology development firms realize that their treatment costs need to decrease to be competitive with other alternatives."

The Great Lakes have been a test bed for contaminated sediment management for over 20 years because a large proportion of the material dredged from the lakes is contaminated and open-water disposal has been impossible since the early 1970s. The results of an EPA program on assessing and remediating contaminated sediments formed the backbone of the technologies considered in the NRC's 1997 report on contaminated sediments. One challenge for these technologies is that they were developed to manage contaminated sediments from freshwater environments. The high salt concentration in marine and estuarine waters can have a strong and complicating effect, particularly for bioremediation, on the chemical and biological processes and equipment used in the technologies.

In its report, the NRC identified interim control measures that might be necessary, given that cleanup projects are usually slow to be implemented and time-consuming. While plans are being drawn up and permits obtained, currents and changing conditions can redistribute sediments or exacerbate problems. *In situ* management includes natural recovery processes, in-place contaminant isolation by capping, and active treatment through thermal, chemical, or biological processes. The NRC also looked at removing and transporting sediment by hydraulic and

Sediment Quality Advisory Levels

Chemical name	Sediment concentration ($\mu g/g_{oc}$[a])
Acenaphthene	130.000
Benzene	5.700
δ-Benzene hexachloride	13.000
γ-Benzene hexachloride (Lindane)	0.370
Biphenyl	110.000
4-Bromophenyl phenyl ether	130.000
Butyl benzyl phthalate	1,100.000
Chlorobenzene	82.000
Diazinon	0.190
Dibenzofuran	200.000
1,2-Dichlorobenzene	34.000
1,3-Dichlorobenzene	170.000
1,4-Dichlorobenzene	35.000
Di-*n*-butyl phthalate	1,100.000
Dieldrin	11.000
Diethyl phthalate	63.000
Endosulfan mixed isomers	0.540
α-Endosulfan	0.290
β-Endosulfan	1.400
Endrin	4.200
Ethylbenzene	480.000
Fluoranthene	620.000
Fluorene	54.000
Hexachloroethane	100.000
Malathion	0.067
Methoxychlor	1.900
Naphthalene	47.000
Pentachlorobenzene	69.000
Phenanthrene	180.000
1,1,2,2-Tetrachloroethane	160.000
Tetrachloroethene	53.000
Tetrachloromethane	120.000
Toluene	89.000
Toxaphene	10.000
Tribromomethane (Bromoform)	65.000
1,2,4-Trichlorobenzene	920.000
1,1,1-Trichloroethane	17.000
Trichloroethene	210.000
m-Xylene	2.500

[a] $\mu g/g_{oc}$, microgram per gram organic carbon

Adapted from: U.S. EPA. The incidence and severity of sediment contamination in surface waters of the United States. Volume I: National Sediment Quality Survey. EPA-823-R-97-006. Washington, DC:Environmental Protection Agency,1997.

mechanical dredges, pipelines, and barges. Finally, a dozen *ex situ* technologies for treatment and containment were examined (see "Big Apple Blight" below).

Questions

Innovative technologies and solutions to contaminated sediment are applauded by environmental groups that have long complained that the USACE is too anxious to dredge without considering the impact, and the EPA is too tardy in inventorying contaminated sediments, establishing sediment cleanup criteria, and controlling the sources of contamination. Only when it affected the economics of shipping did contaminated sediments get serious attention, according to Cynthia Zipf, executive director of Clean Ocean Action, an advocacy group based in Sandy Hook, New Jersey. In addressing the problem, she compares contaminated sediments to a disease: "The one thing you don't want to do is take it to where it can spread [as with open ocean disposal]. You can confine it in a subaqueous pit. You can treat it by solidification or decontamination and use it for remediation material. Or you can cure it by preventing pollution in the first place."

John Tiedemann, chief scientist at Clean Ocean Action, elaborates, "There is no comprehensive list to screen or test the sediment so evaluations must look at toxicity and contamination uptake in the form of bioassays or bioaccumulation. Cleanup is still a somewhat subjective analysis because there are no numerical criteria to tell you how much you have to dredge and when a site has been remediated."

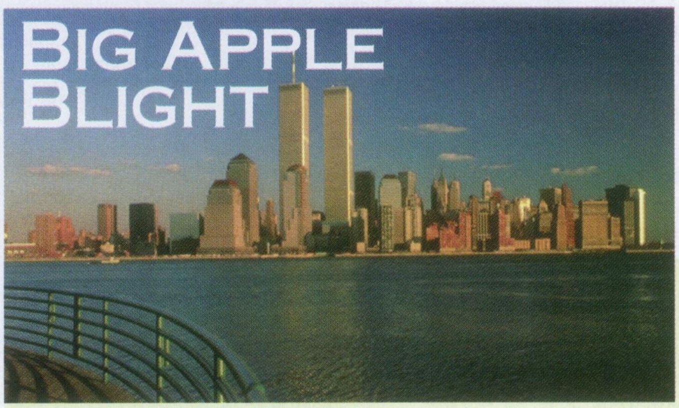
At the Midwest office of the Sierra Club, based in Madison, Wisconsin, policy specialist Emily Green notes, "It's an issue of cost and a lack of an overreaching framework. Now we're seeing sites being cleaned up to different standards, some based on technical feasibility, some on cost, and some on human health considerations. We need more research to draw the link between contamination in fish and the impact on human health. How much does contamination bioaccumulate?"

Green says that the recently issued EPA sediment quality advisory levels (SQALs) are a step in the right direction, but adds that ultimately they will underestimate the impact on human health and wildlife because they only address benthic animals. "There may not be a single number [reflecting bioaccumulation], but we need more research and guidance," she says.

Standard Bearers

The EPA agrees on the need for scientific criteria and the SQALs are progress toward this goal, although considerable work remains. Elizabeth Southerland, acting director of the EPA's standard and applied science division, says, "The Clean Water Act tells the EPA to put out criteria guidance so that states can adopt enforceable water quality standards that identify what levels of contamination are protective of aquatic life and human health. In the 1980s, we came up with criteria for chemical concentrations in the water. In the 1990s, we're trying to come up with chemical concentrations in sediments for both aquatic life protection and human health." The USACE generally opposes specific criteria out of concern that they will be used as

BIG APPLE BLIGHT



The Port of New York/New Jersey contains the country's most complex and contaminated sediment environment. The sediment contains a mixture of contaminants including dioxins and furans, polycyclic aromatic hydrocarbons and polychlorinated biphenyls, pesticides such as DDT and DDE, high concentrations of metals from multiple sources, and pollution from the many Superfund sites that fall within the port's aquatic boundaries. With dredging options becoming increasingly limited, international trade is taking advantage of other ports that can accept deeper-draft ships. A decline in shipping will have a great economic impact; trade through the harbor generates an estimated $20 billion per year in economic activity and is responsible for over 180,000 jobs. An estimated 4 million cubic meters of sediment are dredged each year from navigation channels and public and private berthing areas.

As the result of restrictions on dredged material that could be dumped in the ocean, along with citizen protest, the traditional disposal site off the New Jersey coast (known as the Mud Dump Site) was closed to the most contaminated levels of sediment in September 1997. Clean sediment will be used to cap and remediate the site, now designated an Historical Areas Remediation Site. As one component of the Dredged Material Management Plan for the Port of New York and New Jersey, a public–private partnership was formed of government agencies, community groups, universities, and industry to develop decontamination alternatives.

"The intent is to use the technologies on dredged material and contaminated sediment from within and outside federal navigation channels that may lend itself to 'hot spot' remediation," says Eric Stern, the regional contaminated sediment program manager for the EPA's Region 2 in New York. "It's a public–private partnership because the congressional authorization was not enough to fulfill the mandate of demonstrating up to 500,000 cubic yards of New York/New Jersey dredged material on a yearly basis. The federal government is seeding the development of technology by taking the vendors through the bench, pilot, and full-scale commercial testing. To date, $11.5 million has been appropriated to this project." Actually building a decontamination facility is expected to cost $15–30 million for a facility that can process up to 500,000 cubic yards of material annually.

Stern explains that the decontamination technologies were developed for soils first, and that sediments require a different level of treatability because of moisture content, total organic content, salinity, and the presence of silts and clays. The matrix of contaminants differs from land-based contamination where usually one type of contaminant is found in a location. As a result, a treatment train approach is needed that can handle a range of multiple organics and metal contaminants.

Initially, twelve technologies were bench-tested. The variety of contaminants and differing concentration levels made it fitting to look for different technologies that can be applied at specific concentration levels. Some technologies work at ambient or low temperature, others work at intermediate temperatures but do not destroy the sediments' organic constituents. High-temperature strict pass–fail numbers, providing no latitude for dredged material disposal.

Southerland explains that the EPA approach has been to identify the element that binds contaminants to sediment and apply a theory known as equilibrium partitioning. In 1990, total organic content (TOC) was identified as the binding agent for nonionic organic chemicals such as PAHs and pesticides. The EPA then proposed related contaminated sediment criteria based on TOC. The use of these sediment criteria would require that site-specific TOC be measured and then the allowable chemical load for that site-specific sediment could be calculated. It's an approach based on chemical theory that differs from the empirical approach taken by the NOAA when it decided it would be simpler to, by monitoring, establish a correlation between contamination levels and the health of aquatic organisms.

Southerland is pleased that Superfund remediation is now conducted using SQALs as cleanup goals. However, the SQALs are not cleanup standards and may not be achieved by remediation projects due to cost or other factors. She says the EPA will next propose SQALs for metal mixtures and PAH mixtures. It turns out that PAHs almost always occur in groups and synergistic effects make them more toxic than if they occurred alone. The EPA does not have a schedule for determining SQALs for human health protection, but the EPA does plan to propose that water column human health criteria be based on bioaccumulation factors that incorporate pollutant contributions from sediment.

What's in the Harbor Sediment?

Anthracene
Arsenic
Benzo(*a*)anthracene
Cadmium
Chromium
Chrysene
Copper
Lead
Mercury
OCDD
TCDD
Zinc

Adapted from: Stern EA, Donato KR, Clesceri NL, Jones KW. Integrated sediment decontamination for the New York/New Jersey harbor. Presented at the U.S. Environmental Protection Agency National Conference on Management and Treatment of Contaminated Sediments, 13–14 May 1997, Cincinnati, OH.

"Harbors are at the end of waterways and become contamination sinks," Southerland says. "Port authorities should work with their state water quality agencies to focus on upstream cleanup and pollution control." She believes that SQALs are important because they will allow upstream sources to be identified.

Upstream controls are also a recommendation of the NRC report. In addition, it recommends developing sophisticated cost and risk analysis techniques for managing existing contaminants, and more research and development funding for monitoring technologies to pinpoint underwater contamination. By expanding the CWA's total maximum daily load program, individual states and the EPA could set limits on pollution sources based on total pollution levels in a water body. Legal and enforcement tools such as Superfund could be used to get upstream polluters to help pay for contaminated sediment management. In the end, cooperation among interest groups will be the only path to cleaning the harbors.

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technologies are most applicable to the most contaminated sediments, but may be the least acceptable to the public and the most difficult to permit. Of the twelve technologies, six have undergone pilot tests and Stern is planning a demonstration of up to three of these that will lead to the commercialization phase by 1999:

- A thermochemical process that uses a rotary kiln (Institute of Gas Technology, Des Plaines, Iowa)—The end product is a pozzolanic material that can be mixed with portland cement to make a marketable blended-cement product for use in the concrete and construction industries.
- A solvent-extraction process followed by solidification/stabilization using portland cement as the binding agent (Metcalf & Eddy, Inc., Wakefield, Massachusetts)—Potential uses include construction fill, landfill cover, mine reclamation, and capping brownfields and Superfund sites.
- Stand-alone solidification/stabilization using portland cement (Metcalf & Eddy, Inc., Wakefield, Massachusetts)—Potential uses include construction fill, landfill cover, mine reclamation, and capping brownfields and Superfund sites.
- A thermal vitrification process using a plasma melter (Westinghouse Science and Technology Center, Pittsburgh, Pennsylvania)—The end product is a glass-like material that could be used as construction aggregate or roadfill material, or could undergo further processing to make glass-fiber or glass-tile products, which have higher market value.
- Manufactured soil production followed by phytoremediation (U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi)—The potential beneficial use is to serve as a topsoil layer to support vegetative cover for landfill closure, mine reclamation, and capping brownfields and Superfund sites.
- A sediment washing process using biodegradable surfactants, chelating agents, and oxidation to treat metals and organics (BioGenesis Enterprises, Inc., Springfield, Virginia)—The treated material, which has the consistency and look of sediment, can be used to make a manufactured soil product to be used in agriculture, horticulture, forestry, parks and recreation areas, and habitat creation.

"It is often thought that decontamination technologies will be too expensive and will not be ready for active use in the near term," says Stern. "The results of the [Water Resource Development Act] project do not support these conclusions. From a cost standpoint, it seems possible to do decontamination at a total cost that will be equal to and possibly less than the current disposal alternatives. Decontamination approaches have the very positive attributes of returning a product that is environmentally benign and that has a variety of end uses."